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artery disease may occur with an increased consumption of fructose (3). The conclusion by Elliott et al that dietary fructose has only detrimental metabolic and endocrine effects is somewhat misleading. However, Elliott et al do suggest that much more research is needed to fully understand the metabolic effects of dietary fructose, particularly in humans.

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## Reply to TJ Vasankari

Dear Sir:

We agree with Vasankari that dietary fat and inactivity are likely environmental factors contributing to the marked worldwide increase in the prevalence of obesity, and this was noted in our review on the metabolic effects of fructose (1). However, we believe that an increase in fructose consumption also deserves attention as a potential third factor contributing to the escalation of obesity. Because we are not aware of quantitative data regarding the relative contributions of the 3 factors, we consider it premature to conclude that dietary fat and reduced physical activity are “much more probable contributors” to the obesity epidemic. As we and Bray (2) have pointed out, fructose consumption has increased concurrently with the obesity epidemic. Furthermore, because fructose—similarly to dietary fat—does not stimulate insulin secretion, leads to decreased leptin production, and does not suppress the orexigenic gastric hormone ghrelin (3), the lack of effects of long-term fructose consumption on these endocrine systems involved in the regulation of energy homeostasis could lead to increased energy intake, weight gain, and obesity. We therefore regard increased fructose consumption to be a likely contributor to the increased prevalence of obesity in the past 2–3 decades.

Vasankari discusses the inclusion of fructose in the diets of patients with diabetes because of its low glycemic index. In our review we briefly addressed this topic and also cited evidence that the consumption of small catalytic amounts of fructose increases hepatic glucose uptake and reduces glucose excursions after treatment with oral glucose in subjects with type 2 diabetes (1). Thus, we agree that modest amounts of dietary fructose may be beneficial in the dietary management of diabetes.

Although we intentionally did not provide an in-depth discussion of or cite additional literature on studies of fructose consumption in diabetes, we believe that certain issues should be considered before high-fructose diets are recommended for diabetic patients. First, when large amounts of fructose are rapidly consumed, a sufficient amount of fructose may escape hepatic uptake to significantly elevate systemic circulating fructose concentrations. Protein fructosylation could contribute to diabetic complications (4), particularly because fructose is a major product of the polyol-sorbitol pathway and because tissue fructose accumulation has been implicated in diabetic neuropathy and other complications of diabetes. It was reported that consumption of a high-fructose diet increases both the formation of cataracts and of oxidative byproducts in the kidneys of streptozotocin-diabetic rats (5). In nondiabetic rats, fructose consumption for 1 y led to increased glycation (fructosamine and glycated hemoglobin) and markers of lipid peroxidation and aging when compared with animals that consumed glucose (6). The effect of dietary fructose on glycation and oxidation-related products deserves further investigation, and it is important to determine whether increased glycation and oxidation occur in humans consuming high amounts of dietary fructose.

In addition, although not all studies have shown an adverse effect of fructose consumption on lipids, several studies (7–9), including our own (3), showed that—compared with glucose—fructose increases postprandial triacylglycerol. Although this effect is likely to be highly dependent on the amount of fructose consumed, evidence exists that fructose-induced hypertriglyceridemia is magnified in subjects with insulin resistance (10) or hypertriglyceridemia (6, 11). Therefore, caution should be exercised when recommending diets high in fructose to patients with the metabolic syndrome or type 2 diabetes. Furthermore, in preliminary studies, we found that overweight women with normal fasting triacylglycerol concentrations who consumed 25% of energy from fructose-sweetened beverages for 10 wk had markedly increased postprandial triacylglycerol concentrations (compared with a baseline diet high in complex carbohydrate) and significantly elevated concentrations of atherogenic apolipoprotein B (12). In contrast, postprandial triacylglycerol and apolipoprotein B concentrations did not increase in subjects who consumed 25% of energy as glucose, which induced larger postprandial circulating glucose and insulin excursions than did the consumption of complex carbohydrate or fructose. Thus, the consumption of glucose-sweetened beverages—which have a high glycemic index—does not result in adverse changes in the postprandial lipid profile.

In summary, the effects of fructose on postprandial triacylglycerol and apolipoprotein B concentrations suggest that long-term consumption of high amounts of fructose could contribute to the risk of cardiovascular disease. As indicated by some studies, this effect is likely to be exacerbated in subjects with preexisting metabolic disease. Finally, as discussed above, the lack of effects on endocrine systems involved in body weight regulation suggests that the long-term consumption of diets high in fructose may lead to weight gain, obesity, and the development of type 2 diabetes. Clearly, much additional research is needed to more fully understand the metabolic effects of high-fructose diets, particularly in subjects at risk of metabolic diseases, ie, obese, insulin-resistant, or hyperlipidemic persons. Limiting fructose consumption may be a desirable objective in the management of obesity and hyperlipidemia in individual persons and in the prevention of weight gain and its metabolic consequences at the population level.

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## Erratum

Francois CA, Connor SL, Bolewicz LC, Connor WE. Supplementing lactating women with flaxseed oil does not increase docosahexaenoic acid in their milk. *Am J Clin Nutr* 2003;77:226–33.

In Table 1 on page 227, the values for fatty acids 18:1n–9 and 20:1n–9 were interchanged. The value for 18:1n–9 should read 20.5% by wt of total fatty acids, and the value for 20:1n–9 should read 0.0% by wt of total fatty acids.